Decarbonizing Concrete by Using Biochar as Lightweight Aggregate (LWA)

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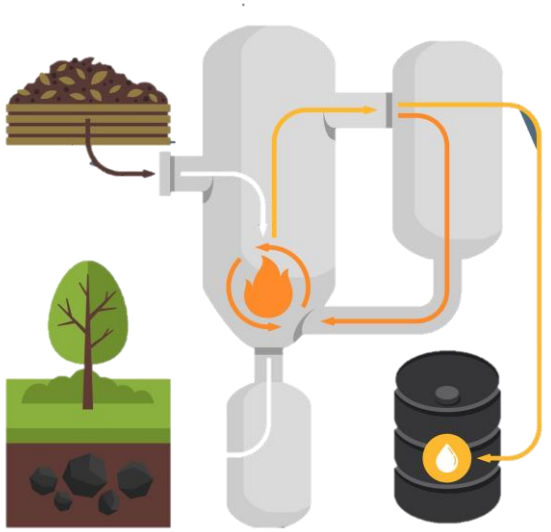
Biochar is a **carbon-rich** material produced when **biomass** undergoes a process called **pyrolysis**.

Feedstock → Pyrolysis → Biochar

Wheat Straw

Wood waste



Owing to its high sequestered CO_2 content, **biochar** could notably reduce the **CO_2 footprint** of concrete structures.

Cement CO_2 footprint
=
+ 0.86 kg CO_2 / kg of cement

Biochar CO_2 footprint
=
- 2.20 –2.70 kg CO_2 / kg of biochar

This research aims to assess if biochar could act as an effective internal curing agent in low w/c systems.

Research questions

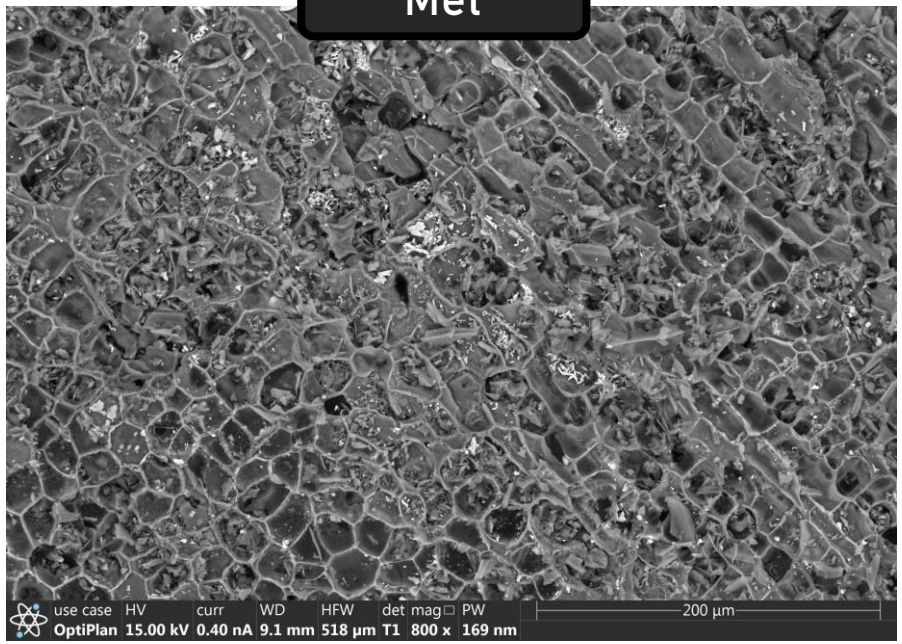
- Could biochar particles keep Internal RH high and control autogenous shrinkage in low w/c systems?
- Does biochar comply with ASTM C1761 requirements for LWAs?
- How does grinding impact biochar's internal curing capabilities?
- How does biochar as LWA affect compressive strength, air content, and flowability?
- How does biochar as LWA impact cement hydration?

The present study utilizes biochar from 2 different manufacturers in **ground** and **unground** form as **sand replacement.**

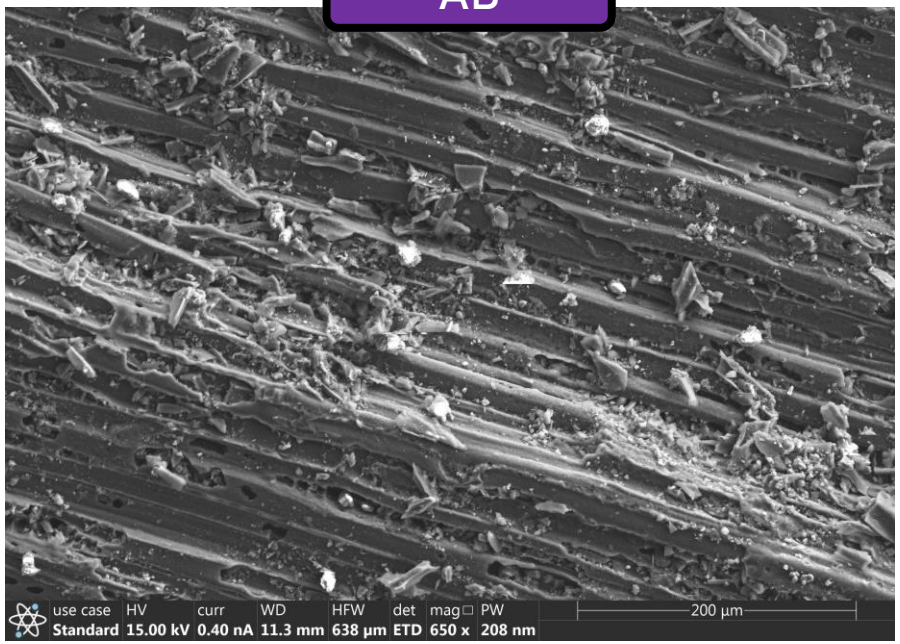
	METZLER BIOCHAR	AMERICAN BIOCHAR COMPANY
Feedstock	Mixed Hardwood Fiber	Southern Yellow Pine Species
Pyrolysis Temp.	700°C	
Carbon Content	89.9 wt.%	77.2 wt.%
Ground-Unground ID	Met – Met60	AB – AB15

The porous nature of biochar could introduce this material as a suitable **LWA** with **internal curing** capabilities.

Met



AB

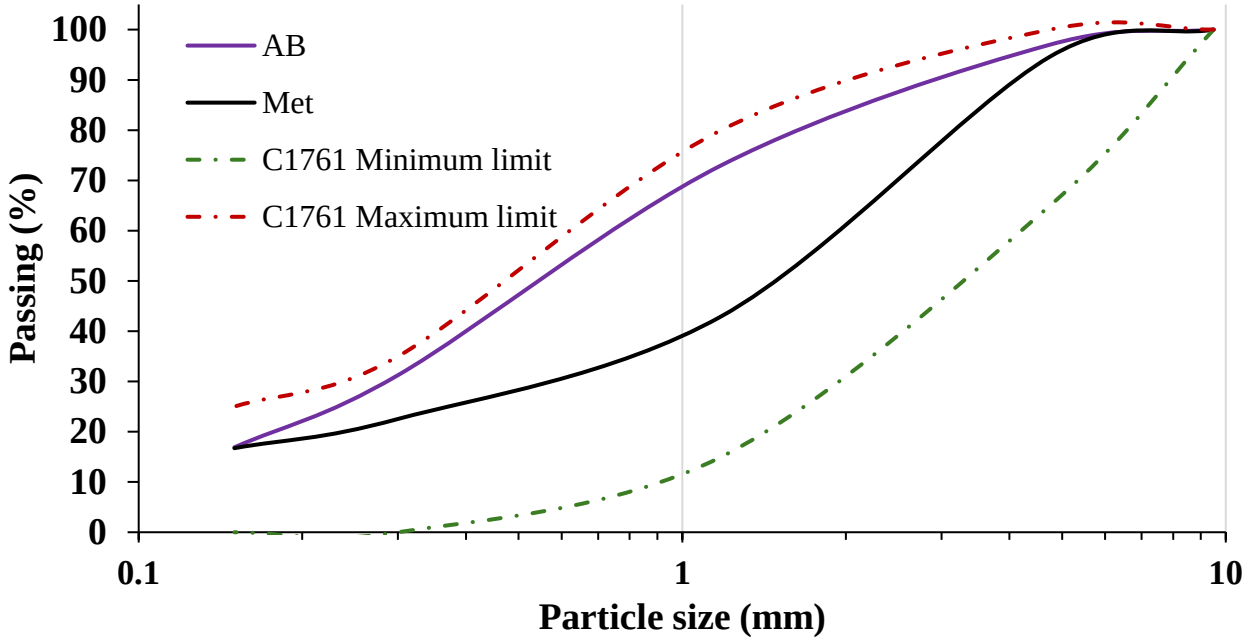


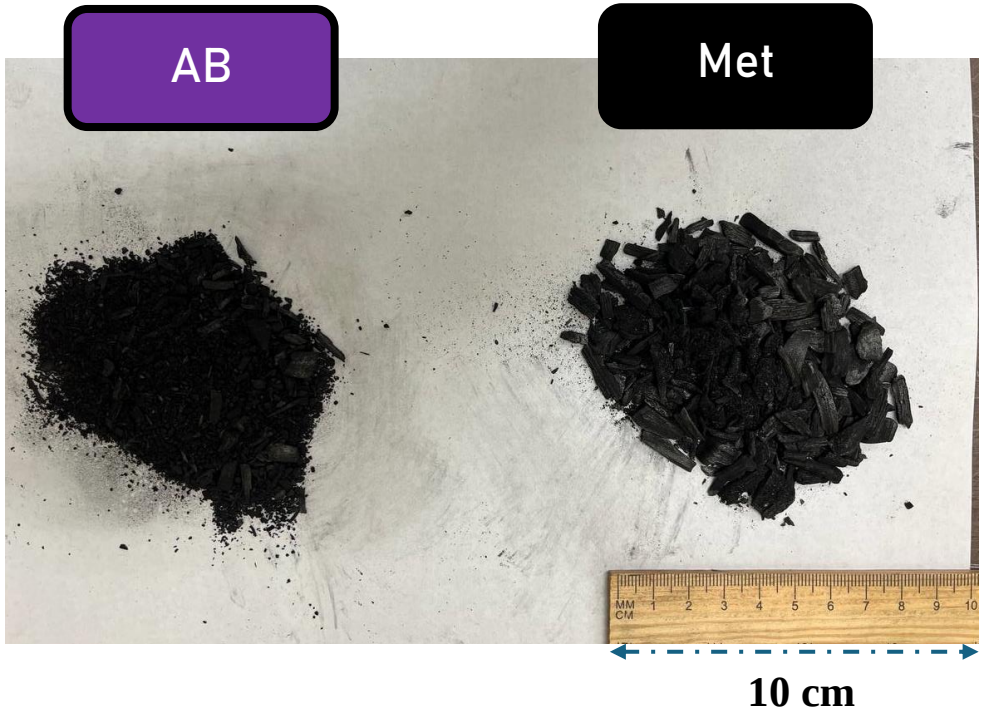
Biochar ID	OD Relative Apparent Density
Met	0.47
AB	0.72

Normal Sand OD Relative Apparent Density
=
2.62

Unground biochar particles had notably high water absorption capacity (Abs.) while satisfying ASTM C1761 gradation requirements.

Unground form

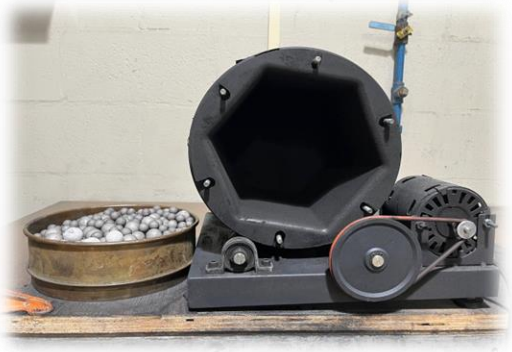


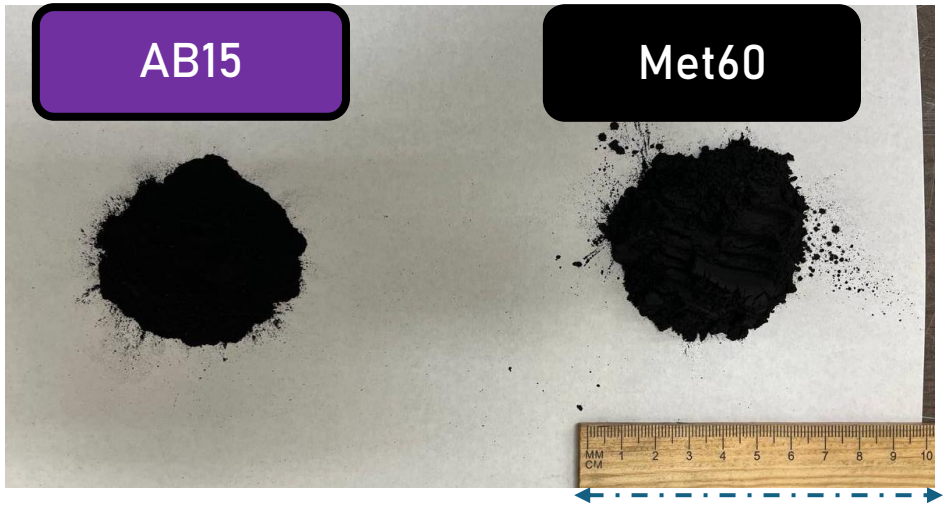


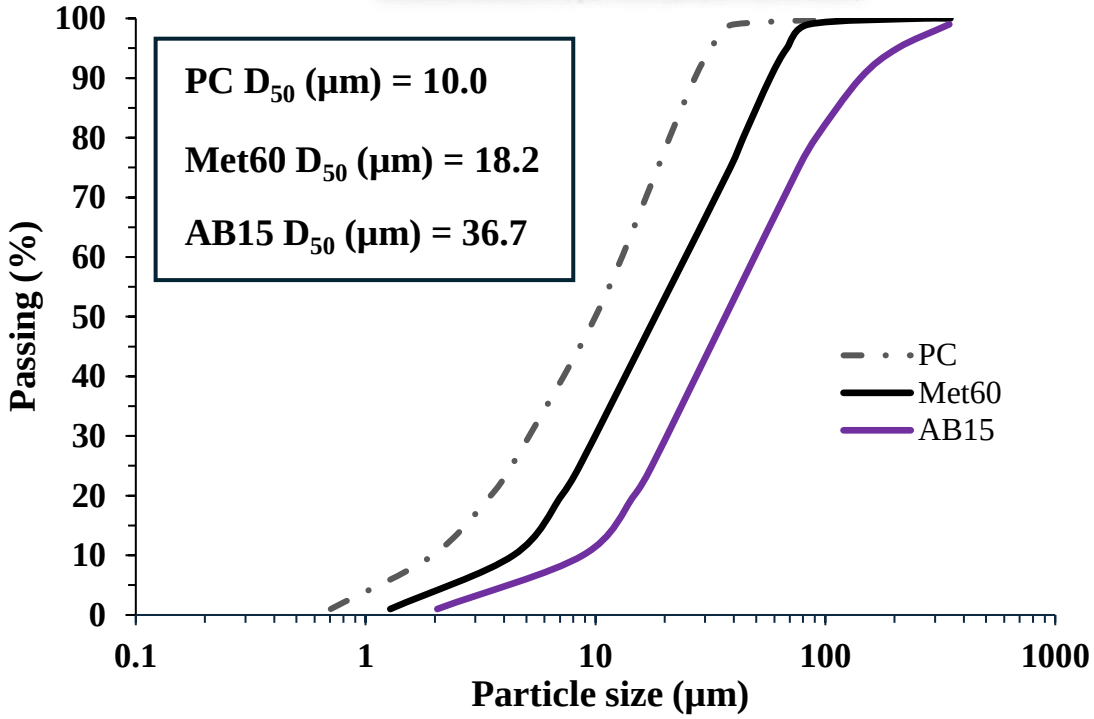
Biochar ID	72-hour Abs. (%)	Desorption rate (% of 72-hour Abs.)
Met	244.0	88.4
AB	131.2	79.5

Ground biochars have high Abs., but their desorption rate is lower than unground form.

Ground form







Deducting the cumulative intrusion volume of any pores larger than D50 from WAC of unground form

Biochar ID	72-hour Abs. (%)	Desorption rate (% of 72-hour Abs.)
Met60	230.2	80.9
AB15	131.1	64.7

A **lower desorption** rate necessitates the incorporation of **higher biochar contents** to get the same internal curing effect.

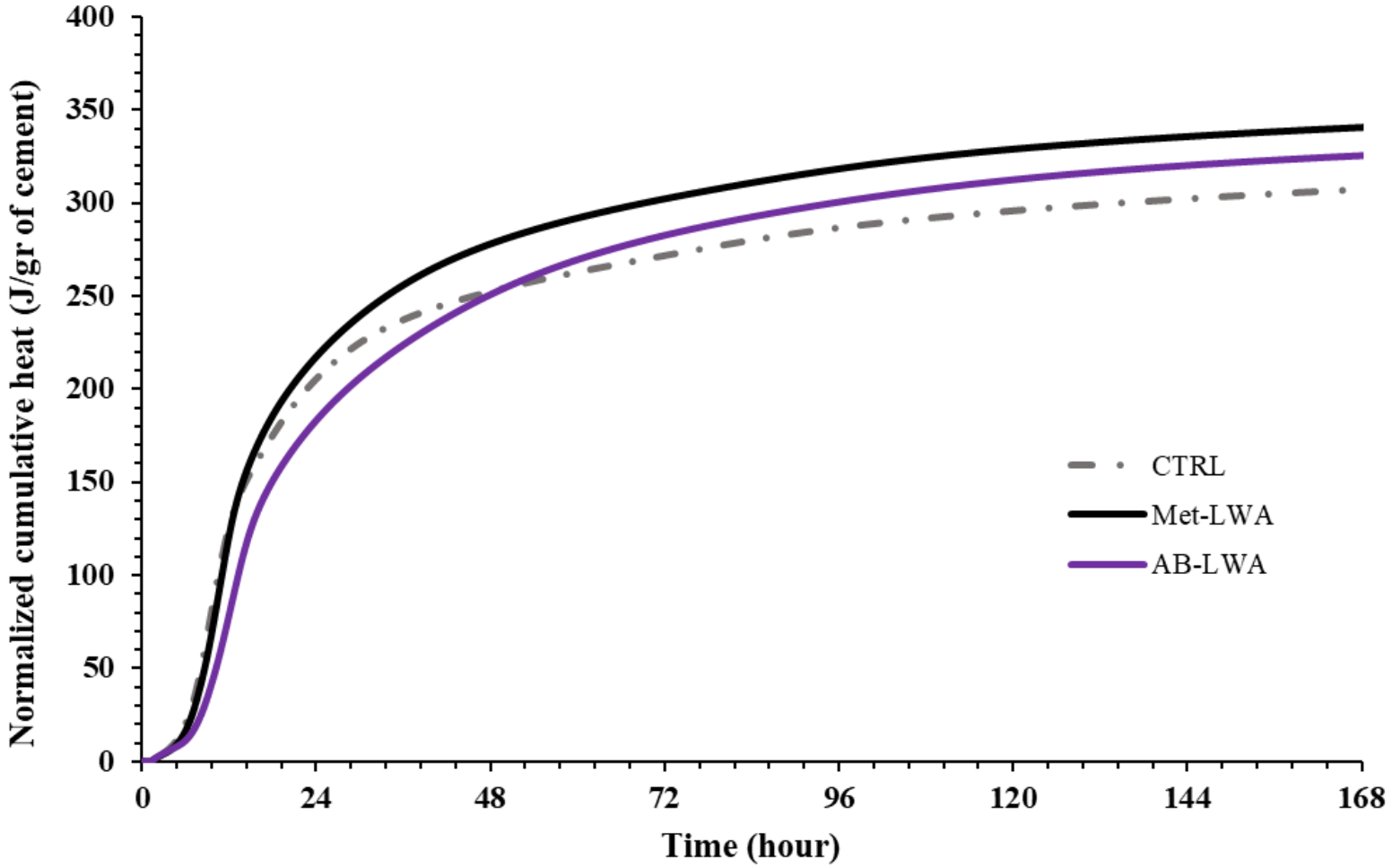
w/c = 0.36

$$M_{LWA} = \frac{C_f * CS * \alpha_{max}}{S * W_{LWA}}$$

- C_f: CM content (kg/m^3)
- CS: Chemical shrinkage (kg of water/ kg of cement)
- α_{max}: Maximum degree of hydration
- M_{LWA}: Mass of LWA (kg/m^3)
- S: Saturation degree
- W_{LWA}: Water mass released by LWA at 94% RH as a function of OD mass

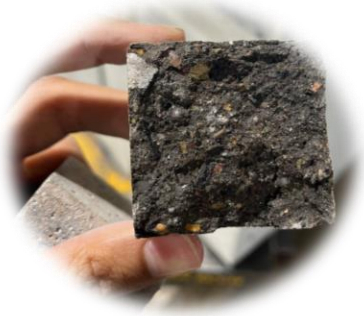
	AB	Met	AB15	Met60
$M_{LWA}(kg/m^3)$	37.8	19.4	51.0	21.2
Replacement level (vol.%)	10.7	7.3	12.4	7.9

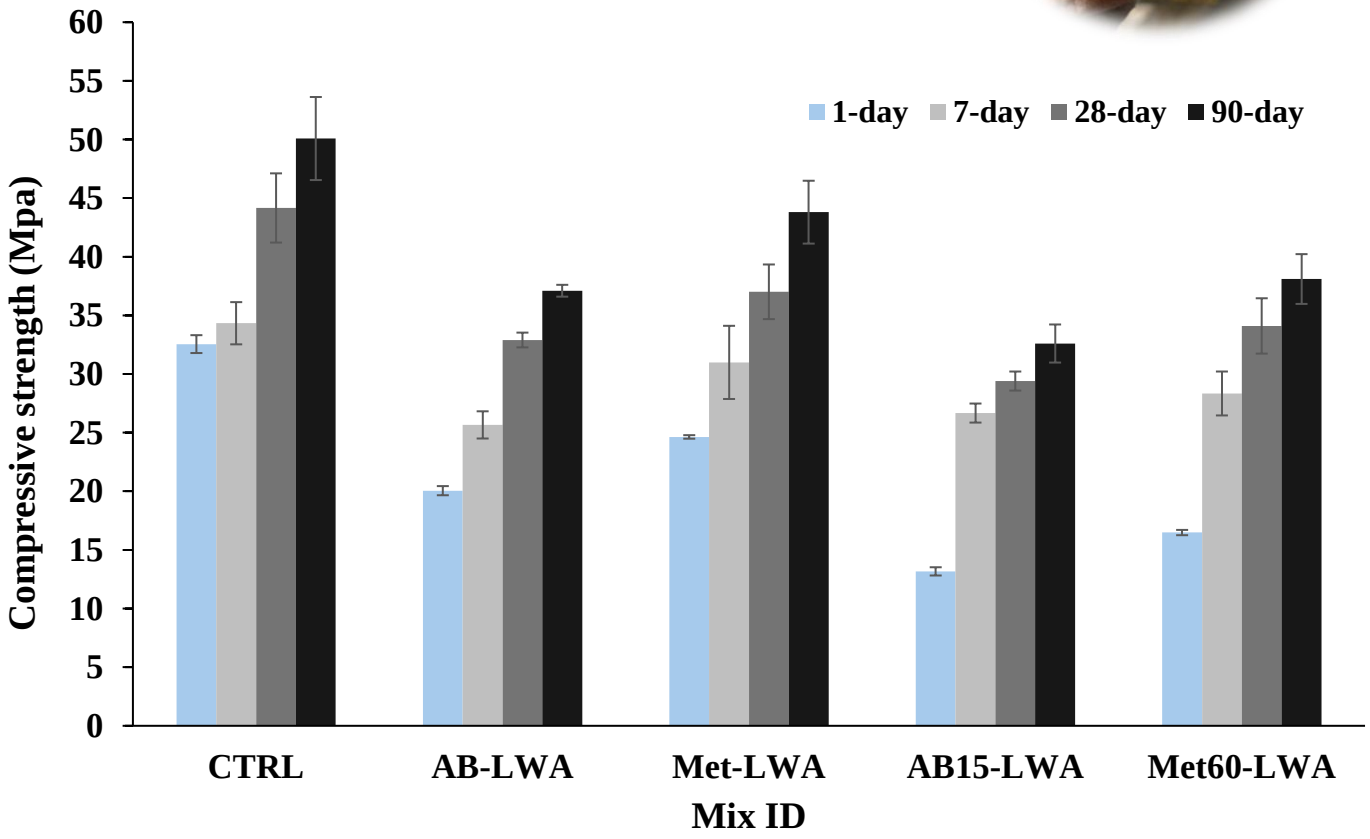
Isothermal calorimetry results demonstrated that cement hydration is improved in the presence of biochar particles as internal curing agents.



Using biochar as sand replacement reduces **compressive strength** and **air content.**

Compressive strength ASTM C109



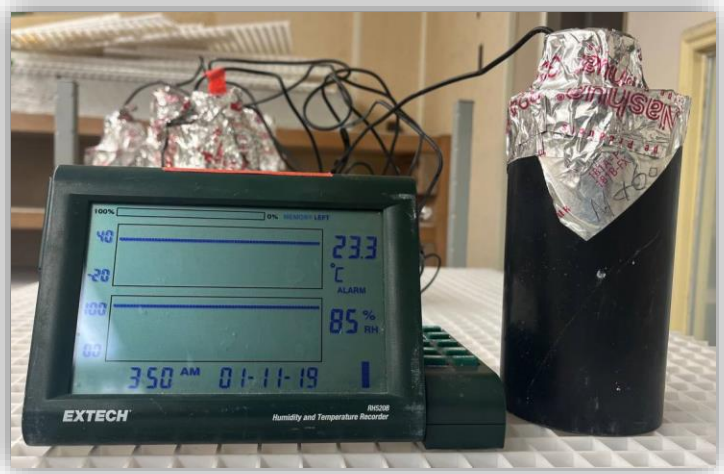


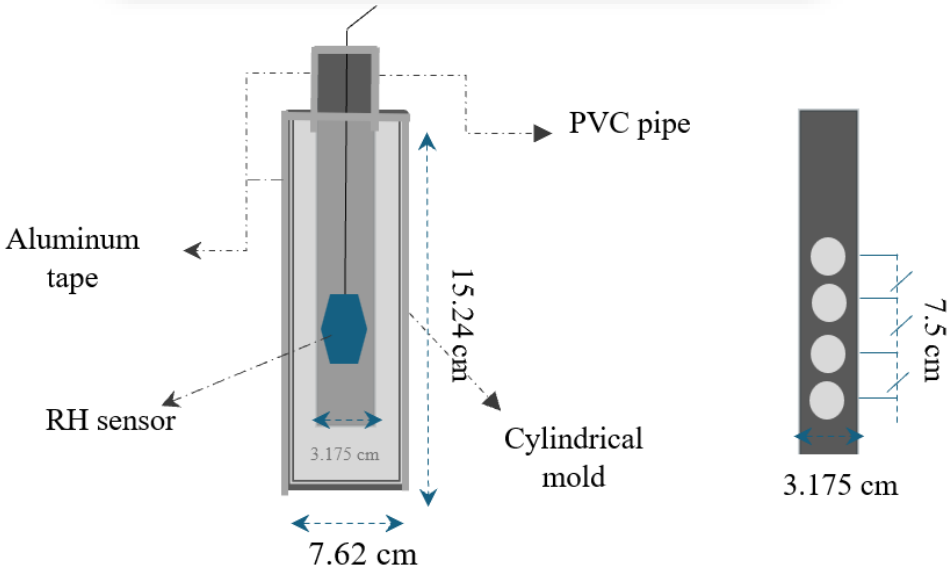
Air content ASTM C185

Flowability ASTM C1437

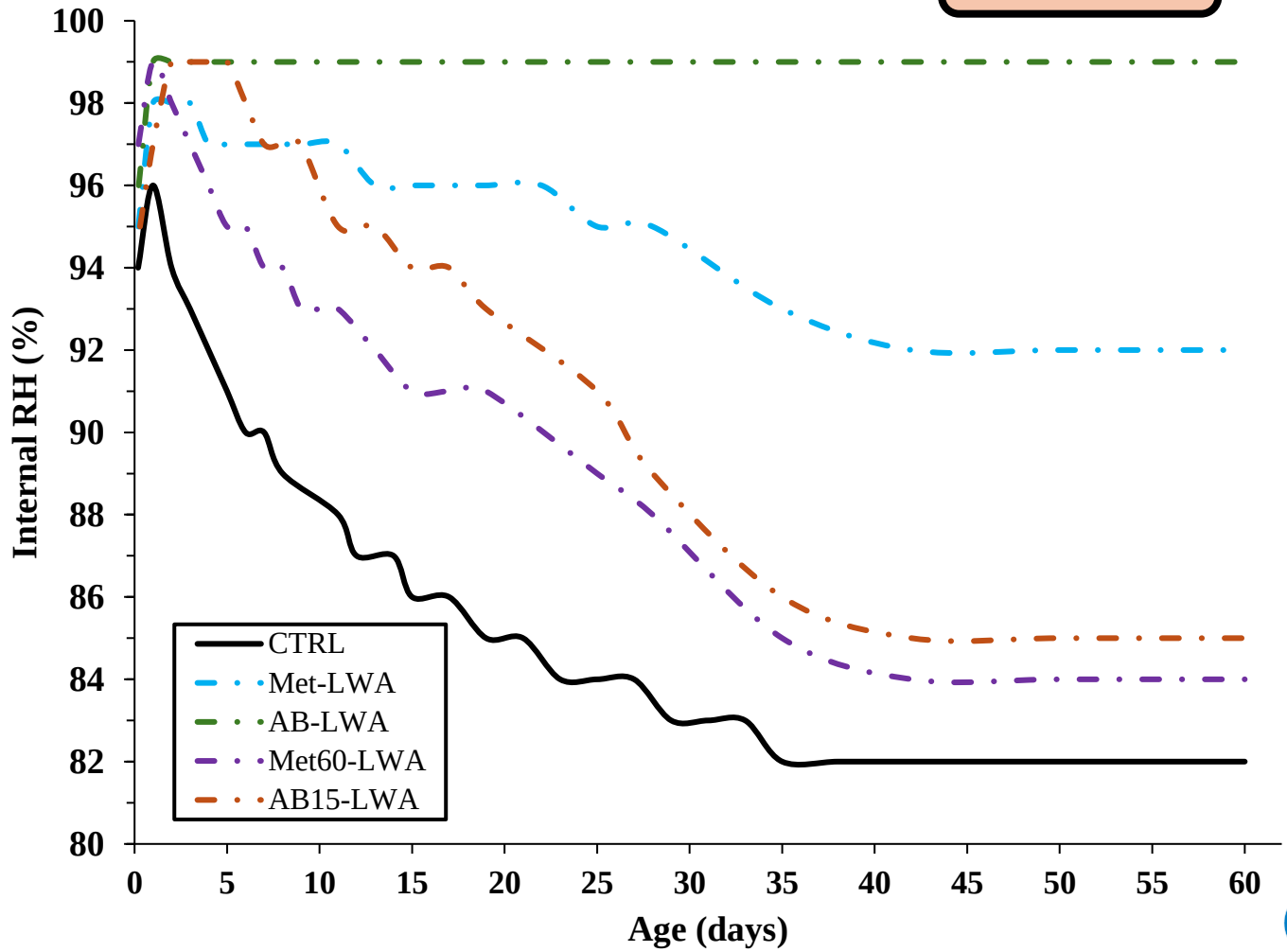
Mixture ID	SP mass (cwt.%)	AE mass(cwt.%)	Air content (%)	Flow number (%)
CTRL	0.54	0.04	7.75	127.2
AB-LWA	0.54	0.04	5.00	117.6
Met-LWA	0.54	0.04	5.50	119.5
AB15-LWA	0.54	0.04	3.75	122.1
Met60-LWA	0.54	0.04	5.00	146.2

As **internal curing** agents, biochar particles could effectively keep **Internal RH** high.





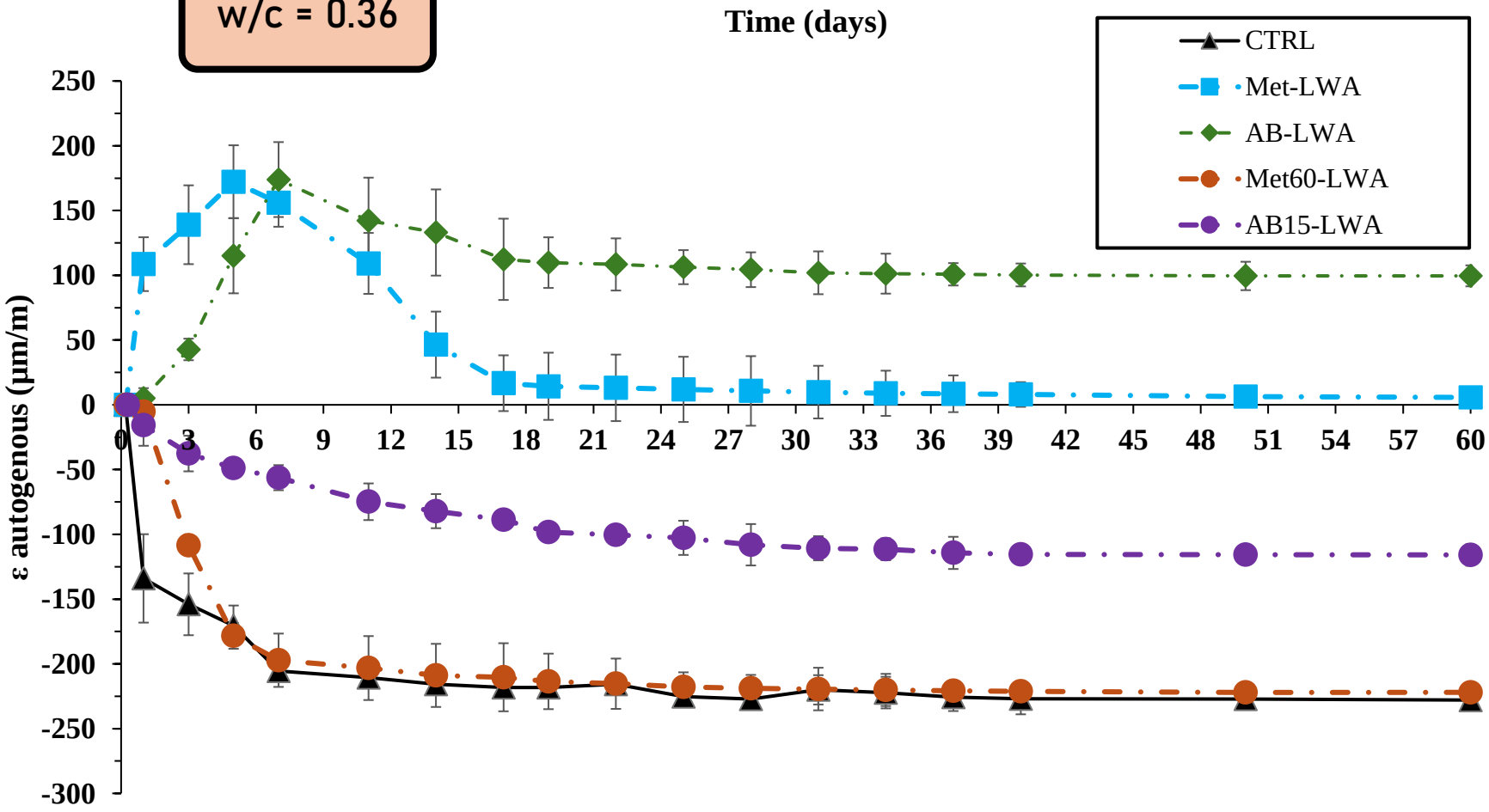
w/c = 0.36



As **internal curing** agents, biochar particles could control autogenous shrinkage effectively.

ASTM C1698

w/c = 0.36



Conclusions

- Biochar particles could effectively keep Internal RH high and control autogenous shrinkage in low w/c systems.
- Unground Met biochar meets ASTM C1761 standards for LWAs, while unground AB biochar only fails the desorption rate requirement.
- Grinding biochar particles adversely affects their internal curing capabilities.
- Biochar particles enhance cement hydration as internal curing agents; however, they reduce strength due to increased overall porosity.
- Added in a presoaked state, biochar particles reduce air content.

Thank you!
Questions?